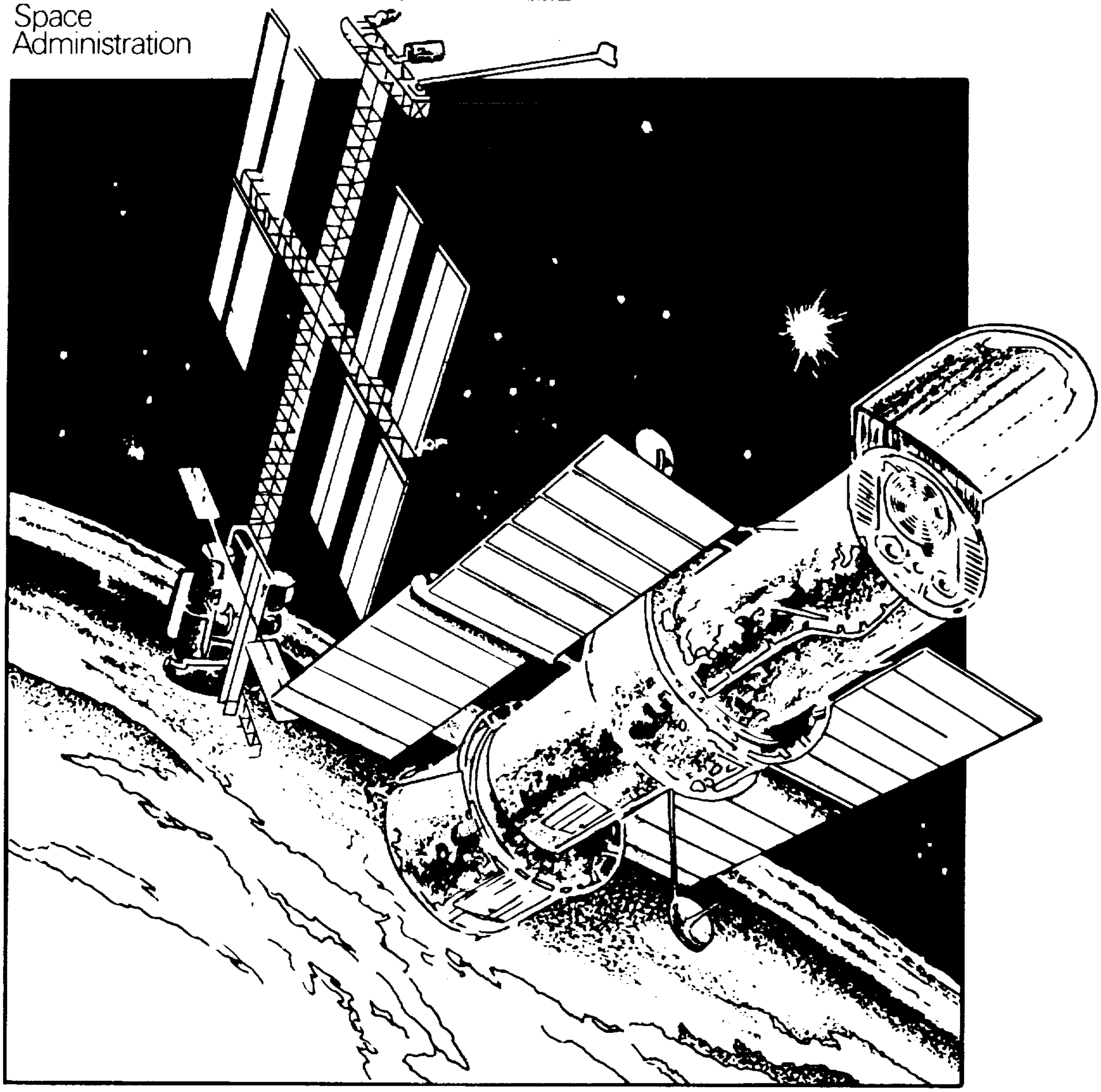
Volume 1
Executive Summary

National
Aeronautics and
Space
Administration



Astrophysics Utilization of the Space Station

(NASA-TM-107850) WORKSHOP ON ASTROPHYSICS UTILIZATION OF THE SPACE STATION. VOLUME 1: EXECUTIVE SUMMARY (NASA) 21 p

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ASTROPHYSICS AND THE SPACE STATION

VOLUME 1

EXECUTIVE SUMMARY

Our nation is embarking on yet another high adventure in space. In January 1984, in his State of the Union address to the Congress and citizens of the United States, President Reagan announced a bold initiative: the establishment of a Space Station as a permanent manned presence in space. Within a decade, this Station will come into service as a center for shaping our future activities in space.

The use of the Space Station for research is of particular interest to the astrophysics community. We are now identifying the ways in which the Space Station can serve us as an observing platform, service center, assembly base, and support node for the missions planned for the near future. As advances in technology enable us to study the sky with greater clarity and precision, the Space Station will provide great opportunities for increasing our knowledge of the universe.

Astrophysics Needs are Matched to the Space Station

The Space Station will be important to astrophysics for a number of reasons. First, astrophysics as a scientific discipline can meet most of its scientific objectives with missions in orbits that are compatible with the Space Station (i.e., 28.5-degree inclination at varying altitudes). Because most of the astrophysical information comes to us in the form of radiation (such as visible light), which reaches the Earth equally well at any latitude, orbit inclination is not the most important consideration for most of what we do. By far, the major issue in astrophysics is simply to get above the atmosphere which obscures most of the radiation from celestial sources. Even when the radiation can penetrate to observatories on the Earth's surface, the atmosphere acts as a glowing background against which one can not do astronomy effectively.

We expect that the Space Station will be a versatile multipurpose facility that can serve astrophysics in several important capacities. For example, astrophysicists contemplate using the manned Space Station as an observatory base to carry certain instruments. We also envision using the manned Space Station to service satellites; of particular interest are the observatories which are designed and justified on long-life operations with servicing to repair failures and to upgrade technology. Astrophysics can use the manned Space Station as a base of assembly. At least one project (the

Large Deployable Reflector) has been identified and is being actively pursued in a study/technology development phase; it probably would not be feasible without extended assembly operations in orbit. The Space Station can also serve as a transportation hub and service node for platforms, opening the possibility of making truly permanent observatories for infrared and x-ray astronomy and of putting a whole fleet of Explorer-class payloads into service. It looks very attractive and feasible to maintain and recycle these small platforms from the Space Station. Finally, the Space Station could enhance spacecraft operations by augmenting support functions--acting as a communications node, for example.

Content of the Reports

This set of reports is intended to address near-term scientific priorities for the Astrophysics Program in the context of the new Space Station. The reports have been developed to highlight those key pieces of the Astrophysics Program that fit well within the Space Station concept. In these reports, the strategies outlined in the National Academy of Sciences report, Astronomy and Astrophysics in the 1980's (also known as the Field Committee Report), are implemented by using the Space Station effectively. Thus, this set of documents provides for carrying out the most imperative scientific objectives in astrophysics.

Workshop on Astrophysics Utilization of the Space Station

The reports were developed by convening key leadership from the scientific community, industry, and NASA to work together in defining strategies and concepts for meeting our announced scientific objectives and implementing the Agency's program plans with Space Station utilization. Individuals who are expert in the various areas were identified during late spring of 1984, preliminary drafts of these final products were prepared, and a group of approximately 100 scientists and Agency representatives assembled in a workshop on June 20 and 21, 1984, at the Goddard Space Flight Center in Greenbelt, Maryland. The drafts were discussed by groups of representatives, each group focusing on the concepts in one of the reports. The concepts and ideas were also exposed and discussed before the entire group in large plenary sessions. What has emerged from this endeavor is a conceptual foundation for astrophysics utilization of the Space Station. We intend that NASA use these documents as guidebooks for technical and programmatic considerations during Space Station definition.

SPACE AND SPACE ASTRONOMY: THE NASA ASTROPHYSICS PROGRAM

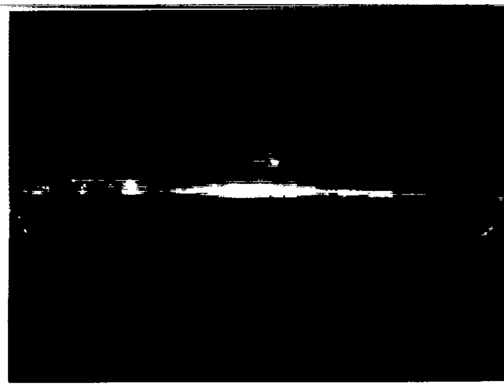
We are stargazers. Since ancient times, we have studied the heavens to understand the mysteries of the universe, its organization, origin, and history. Only for the past 25 years, a blink of the eye in the course of human history, have we been able to study the stars from a vantage point in space. Yet in this brief interval, we have made remarkable progress toward answering the questions that have eluded us for centuries. We have also raised new questions and found the universe to be a far more interesting and active place than we had ever imagined.

Today our study of the universe blends ancient astronomy, modern physics, and state-of-the-art technology. While we still aim to explore and understand, to discover and analyze the universe, our scientific objectives and the instruments required to meet them have grown increasingly elaborate. We now follow a strategy for examining the universe methodically to coax out its secrets: from initial surveys in different parts of the spectrum, we move toward long-duration, detailed studies using the observatories. Our goals are to understand the origin and evolution of the universe and the basic physical laws governing the phenomena that we observe there. The nearest star, our Sun, is a Rosetta stone as we seek to understand how energy is generated there and transported through space in the solar wind.

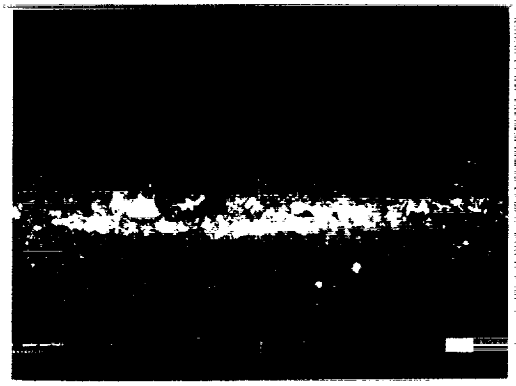
Space Astronomy

In our time, we have risen above the obscuring atmosphere and pursued our research in space. No longer confined to peering at the stars through a "dirty basement window", we have achieved in space a vast view of the universe. With instruments borne on balloons, rockets, and free-flyer satellites, we have achieved greatly improved sensitivity, resolution, and wavelength coverage. Research in space has revolutionized the practice of astronomy and spawned the many new disciplines of astrophysics. A new major challenge is the utilization of a permanent base for the appropriate astrophysical research.

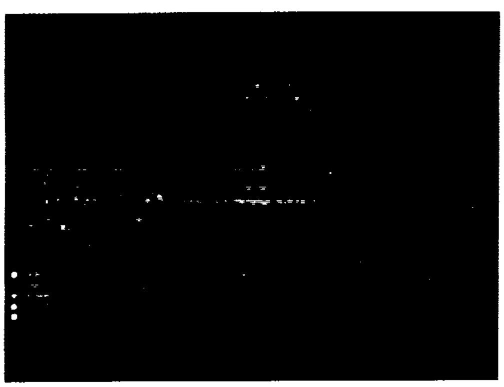
The primary and obvious advantage of doing astrophysics in space is that only there do we have access to all channels of information in the electromagnetic spectrum. Celestial objects emit radiation across the spectrum from lowest-energy, longest-wavelength radio through infrared, visible, ultraviolet, x-rays and highest-energy, shortest-wavelength gamma rays. Virtually all of our knowledge of celestial objects is derived from observation of electromagnetic radiation. Each wavelength band carries unique information about its source and about physical processes occurring there. Of the 20-odd decades of electromagnetic radiation that reach the top of the atmosphere, only 5 decades penetrate to the ground. Thus, on Earth we have access to a mere fraction of the available information; to open all the channels and learn more, we do our research in space. Even for those regions of the spectrum where the atmosphere is relatively transparent, such as the radio and visible bands, it is enormously advantageous to place instruments in space beyond the distorting atmospheric interference.



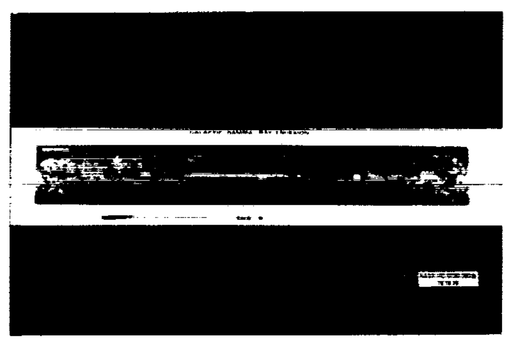
a. With Infrared



b. In Visible Light



c. In X-rays



d. In Gamma Rays

FIGURE 1.1 PICTURES OF THE SKY

Infrared radiation (a), with wavelengths about 10^{-5} m, is invisible to the human eye. Areas that emit infrared radiation are often clouds where stars are forming. Visible light (b), with wavelengths about 10^{-7} m, comes primarily from visible stars and from galaxies above and below the Milky Way. X-rays (c), with wavelengths about 10^{-10} m, are emitted from quasars, pulsars, and black holes. They indicate areas of extremely high temperature and catastrophic events. Gamma rays (d), with wavelengths of about 10^{-12} m, have extremely high energies and indicate areas in space where the most energetic events take place.

Telescopes for Space Astronomy

Those unfamiliar with astronomy often ask why we need so many different kinds of telescopes. Why are not the Palomar and Hubble telescopes, among the largest on Earth and in space, sufficient? The answer, of course, is that they are optical telescopes and optical astronomy reveals only part of the universe (some would say only the "normal" universe). Astronomy in visible wavelengths principally shows us the stars. Even more interesting sights--bizarre objects and cosmic explosions--can be "seen" by other kinds of telescopes sensitive to the invisible wavelengths. Visible light is not the primary output of pulsars, quasars, supernovae, and the like; we learn much more by investigating their radiation in other wavelengths.

Infrared radiation, for example, is emitted from relatively cooler objects, such as the clouds of dust where stars are born or the cinders of

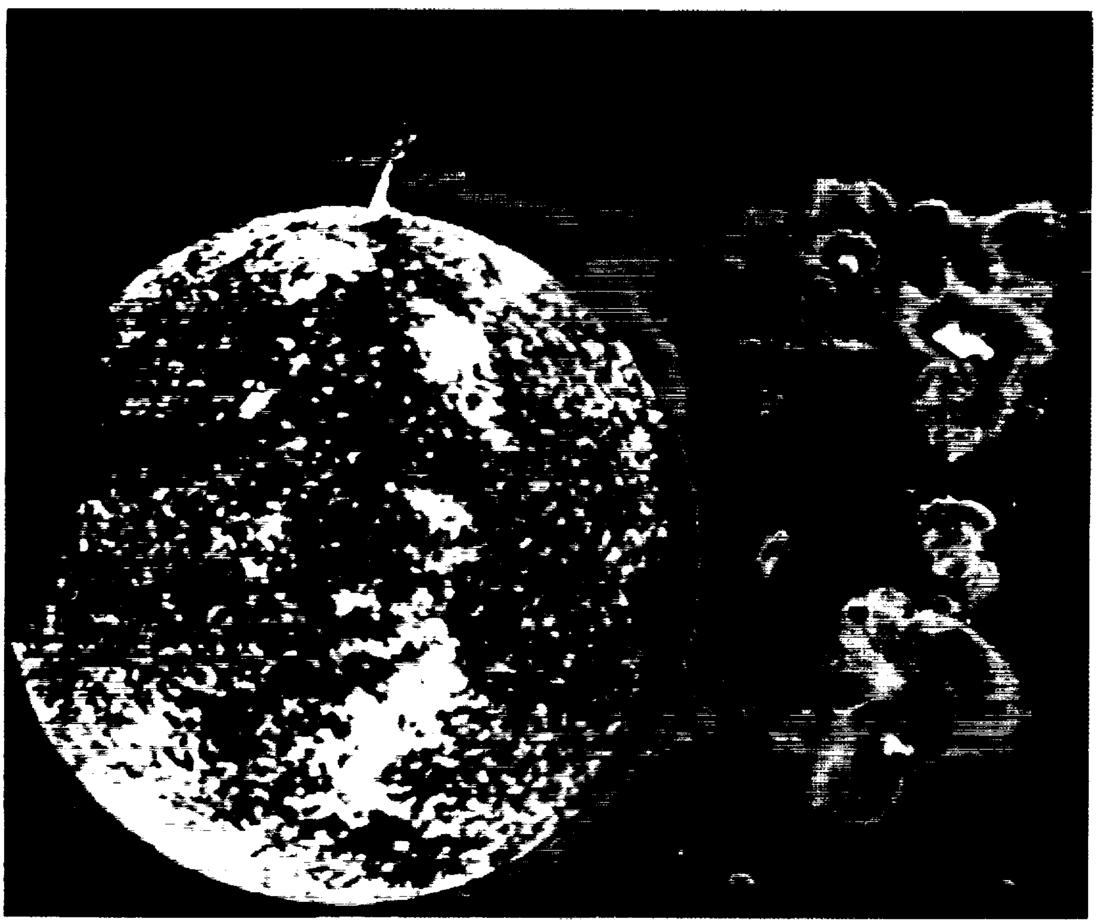


FIGURE 1.2. IMAGE OF THE SUN IN ULTRAVIOLET LIGHT

Images are dispersed by ultraviolet wavelengths in this picture taken on Skylab. Sharp images occur where there is strong ultraviolet emission at a specific wavelength.

burned out stars. X-ray radiation, on the other hand, indicates the presence of gases heated to millions of degrees and catastrophic events often characteristic of the death of stars. Mysterious objects known as quasars, pulsars, and black holes emit X-rays profusely. Gamma rays are released by the most energetic events. As we proceed with our inquiry into the nature of the universe, we must investigate the sky in all wavelengths. Detection in each spectral region requires an entirely different kind of instrument. Separately or in concert, these different instruments are essential to astrophysical research.

Unresolved Questions

In the past 25 years of space astronomy, we have vastly increased the catalog of known celestial objects. For example, we have identified at least 5,000 X-ray sources and a quarter of a million infrared sources, and there is no reason to think our lists are complete yet. We have made startling discoveries about probable events in the universe, and we have pushed the frontiers of knowledge further and deeper into time and space. Yet the successes of our recent work, impressive as they are, have also shown us how much we do not yet understand. Quasars, for instance, are remarkable objects the size of our solar system that emit as much energy as an entire galaxy; but we cannot yet explain the process or mechanism responsible for this powerful phenomenon. There are enough unanswered questions left to engage our attention well into the next generation.

The National Academy of Sciences report Astronomy and Astrophysics for the 1980's presents the major unresolved questions before us today and suggests appropriate strategies for attacking these problems. Before we consider how we might use the Space Station to implement those strategies, let us briefly review the general issues in current astrophysics research:

- Violent events: What exactly are supernovae, pulsars, black holes, and quasars? What is their structure? What physical processes produce such tremendous energy?

- Cosmic backgrounds and large-scale structure of the universe: What is the distribution of matter through the universe? What is the nature and origin of interstellar gas? How can we determine more accurately the distance and time scales of the universe? What are the origin, history, and fate of the universe? Where is the "hidden mass" that our calculations indicate should exist in the universe?

- Evolution of galaxies: How do galaxies form? How do they evolve? How can the different patterns of galaxies be explained? What kinds of activity occur in the nuclei of galaxies?

- Formation of stars and planets: What is the composition of molecular clouds in interstellar space? What role do molecular clouds play in star formation? What is the origin of interstellar dust? What are the origin, history, and fate of our solar system?

- Solar activity: What is happening on the Sun? How are mass and energy transported through the Sun and through space? What is the role of magnetic fields in energy production, storage, transport, and release?
- Forces of nature: Does gravitational radiation exist? How do electromagnetic and nuclear forces interact? Is a unified theory of cosmic processes possible?

The answers to most, if not all, of these questions require prolonged observation, full spectral coverage, higher sensitivity, and increased resolution (angular, spectral, and temporal). We want to look farther, longer, and in sharper focus for those revealing phenomena that will help us explain the cosmos. As we pursue our ambitious research program, we will be taking advantage of both maturing and emerging technologies to gain access to details of the universe that are fainter, more minute, more distant, and more mysterious.

Further Discoveries

We can make a convincing case that discovery keeps pace with technology. The imaginative application of new technology to reigning problems reveals previously inaccessible and unknown phenomena. Martin Harwit, in his intriguing study Cosmic Discovery, argues that there have been perhaps 43 major discoveries in the history of astronomy. Many of these discoveries resulted from new technology applications that enabled astronomers to scrutinize the heavens with greater clarity and precision. With the rapid development of instruments and techniques for astrophysics, we can expect a concurrent burst of discoveries in all parts of the spectrum.

If Harwit is correct about the finite number of significant kinds of objects in the universe and the relatively few discovered thus far, then we may, with new technology, equal or exceed the number of all previous discoveries. The rest of the universe may well be within the scope of observation during our generation. The challenge to astrophysics is to use new technology to make the remaining discoveries. We expect the Space Station to figure prominently in our efforts to meet this challenge.

Thus, many believe that we live in a unique era. It is arguable that the next few decades will reveal the nature and scope of the universe to our generation. Our space observatories are the exploring "ships" of the 20th and 21st centuries as the vessels of the early explorers were to Spain and Portugal in the 15th century. To carry out the exploration of the universe under American leadership is to continue our national spirit--the technological and scientific advances will help sustain our technological excellence.

ASTROPHYSICS AND THE SPACE STATION

Since no field of science has ever benefited so dramatically from new technologies as space astrophysics, it is very important to observe that the Space Station is a grand technical advance that will bring a tremendous leap forward in our capabilities for astrophysics research.

The impact of the Space Station and its technology on the NASA Astrophysics Program can be seen in Table 1, which maps the scientific requirements from each discipline into the key capabilities for accomplishing the investigation. Check marks indicate the current plan, while x's show capabilities needed in the more distant future. In every case, we have deleted reference to capabilities that could be used in principle but which did not make sound, fundamental sense. In the following sections, we discuss each of these capabilities.

The Space Station as an Observatory

To answer many of the open questions in astrophysics today, we need long observation periods, large instruments, and evolutionary instrument complements. The permanent Space Station certainly can serve as a platform for long-term investigations. Unlike an unmanned scientific satellite, the Space Station will be inhabited by crews of scientists and technicians who can operate, maintain, and use instruments for years of productive observation. Furthermore, the Space Station will be capable of bearing much larger instruments than a spacecraft can carry in orbit, and it can accommodate large, growing sets of instruments.

SPACE STATION UTILIZATION ASTROPHYSICS

	MANNED BASE			PLATFORMS			
	OBSERV. PLATFORM	SERVICE BASE	ASSEMBLY BASE	EXPLORER CLASS		OBSERV. CLASS	
				L	P	L	P
SOLAR							
INTERIOR (EXPL.)		✓			✓		
SURFACE (SOT/ASO)	✓	✓					
ATMOS (POF/ASO)	✓	✓					
ATMOS (POF/ASO)		✓		✓			
STARPROBE			X				
HIGH ENERGY							
X-RAY (AXAF)		✓				✓	
X-RAY(EXPL.)		✓		✓			
X-RAY (HTM)		✓	X			X	
G-RAY (GRO)		✓				✓	
G-RAY (EXPL.)		✓		✓			
COS RAY (CRNE & TRIC)	✓	✓					
COS RAY (HEIE)					X		X
COS RAY (HESSA)	X	X	X				
ASTRONOMY							
RADIO (OVLBI)		✓	X		✓	X	
SUB-MM (LDR)		✓	✓			✓	
IR (SIRTF)		✓				✓	✓
UV/VIS (ST)		✓				✓	
UV/VIS (STARLAB)		✓				X	
UV/EUV (FUSE)		✓		✓			
INTERFEROMETERS		X	X			X	
RELATIVITY							
GRAVITY WAVES		X	X				
GRAVITY PROBE-B							✓

✓ = CURRENT L = LOW INCLINATION SERVICED BY SPACE STATION
X = FUTURE P = POLAR INCLINATION SERVICED BY SHUTTLE

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At present, it appears that the disciplines of solar physics and cosmic ray physics can best take advantage of this attribute of the Space Station to achieve our near-term scientific objectives. Because solar physics instruments require stable pointing on short time-scales and, due to their warm surfaces, are less susceptible to contamination than other kinds of detectors, they are well suited to be attached payloads on the Space Station. Furthermore, as the Skylab experience demonstrated, solar physics investigations benefit from the quick-response capability of a manned mission when targets of opportunity and unforeseen events occur. Cosmic ray instruments, which chiefly require a clear view of space, also will benefit from the stable mounting and load-carrying capability of the Space Station. There it will be possible to mount very large instruments, with modest pointing demands, for long observing periods.

The Advanced Solar Observatory (ASO), starting with the Pinhole/Occulter Facility (P/OF) and the High Resolution Cluster of telescopes built around the Solar Optical Telescope (SOT), will be the major observatory for solar physics in the 1990's. While SOT will observe infrared, visible, and ultraviolet emissions from the Sun, P/OF will provide very high angular resolution for hard x-ray imaging of flares and allow investigations of the transport of heat into the corona at its base. Because these instruments are designed to be operated initially as part of the Spacelab program on the Shuttle, we expect that they can be accommodated on the Space Station without major technical problems. If anything, the Space Station should be more stable and have less contamination than the Shuttle, and the Station will enable the evolution of solar instruments as the ASO matures.

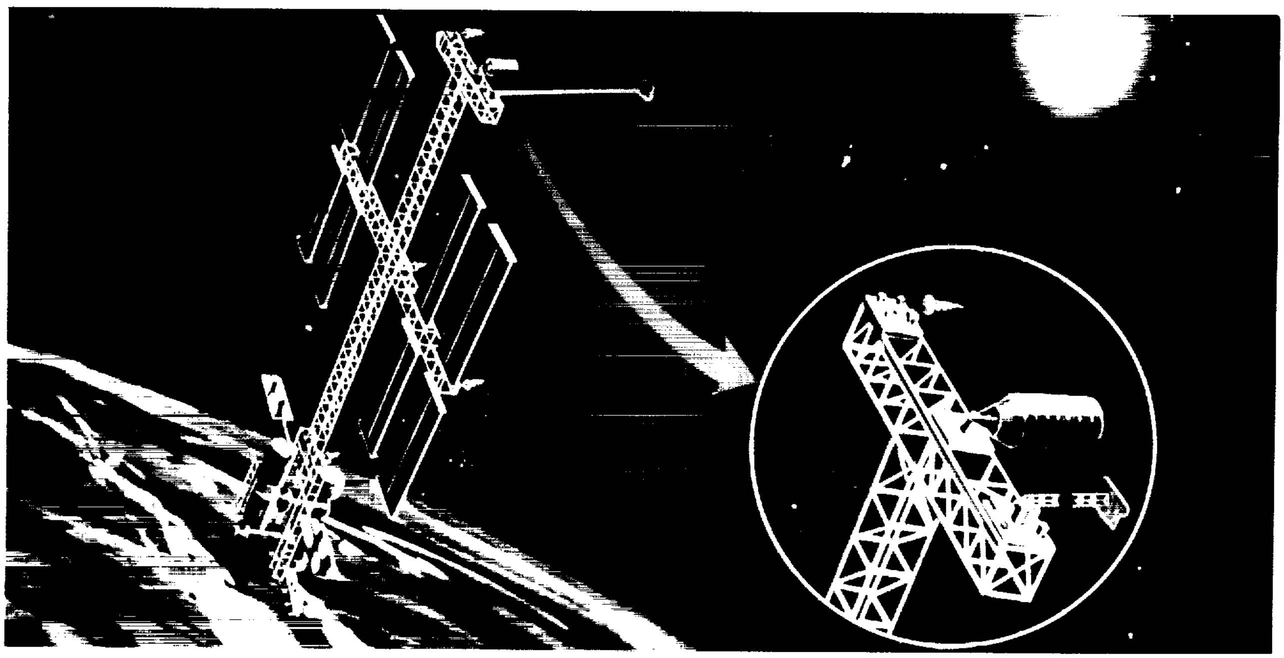


FIGURE 1.3. THE ADVANCED SOLAR OBSERVATORY

This major observatory for solar physics will observe the Sun in wavelengths from very low radio waves through nuclear gamma rays.

ORIGINAL PAGE
COLOR PHOTOGRAPH

Cosmic ray instruments are well suited to the manned base because they have very low demands for pointing, power, and telemetry. Internally, these instruments must be complex so they can measure the charge and energy of relativistic nuclei to determine where they originated and how they achieved their extreme energies. However, all they require from the Space Station is a clear view of space over a wide field of view (30 to 60 degrees). The power demands (never more than 500 Watts) and data rates (less than 100 kbits/sec) are modest compared to the capabilities of the manned base. Like the ASO instruments, the cosmic ray experiments will be developed through the Spacelab program and will make their first exploratory observations from the Shuttle.

One key lesson we have learned from experimental programs such as Spacelab that used the Space Shuttle as an observation platform is that small experiments fill a vital role. We are beginning to implement low-cost experimental programs, such as Spartan and Hitchhiker, for the Space Shuttle. These programs have three objectives:

(1) Instrument testing and development. Low-cost, simple ways to gain frequent access to space are essential to develop the advanced instrumentation for tomorrow's major missions.

(2) Training and education. Activities have time scales which are far too lengthy to involve graduate students. Low-cost, simple space experiments provide the means to educate the coming generation of space scientists.

(3) Science. There are many specialized measurements which generate science results of the first rank. These opportunities, when provided frequently (and hence at low cost), ensure that scientists of the highest quality remain in space research between the larger mission opportunities.

As we embark on the Space Station project, it is vital that frequent access to space is retained for simple experiments. Many astrophysics experiments can make do with the pointing provided by the Shuttle attitude control system, but most astrophysics experiments require fine pointing (~1 sec). To provide fine pointing for simple experiments from the Shuttle or the Space Station implies technical and operational complexity which is inconsistent with the goals of low cost and simplicity.

The Spartan concept removes this complexity for simple instruments needing fine pointing (see Volume 5), and we should reserve small attached payloads for experiments with minimal pointing constraints. Our current estimates are that about 15 flight opportunities per year would be appropriate for Spartan experiments and up to five per year for Hitchhiker class (non-fine-pointed) experiments.

It is essential to include these kinds of experiments in the Space Station era. We strongly recommend that the Space Station program incorporate these capabilities using a combination of attachment ports on the manned base and use of subsatellites.

The ASO, the cosmic-ray experiments, and the opportunities for small attached payloads are described in Volume 2 of this report.

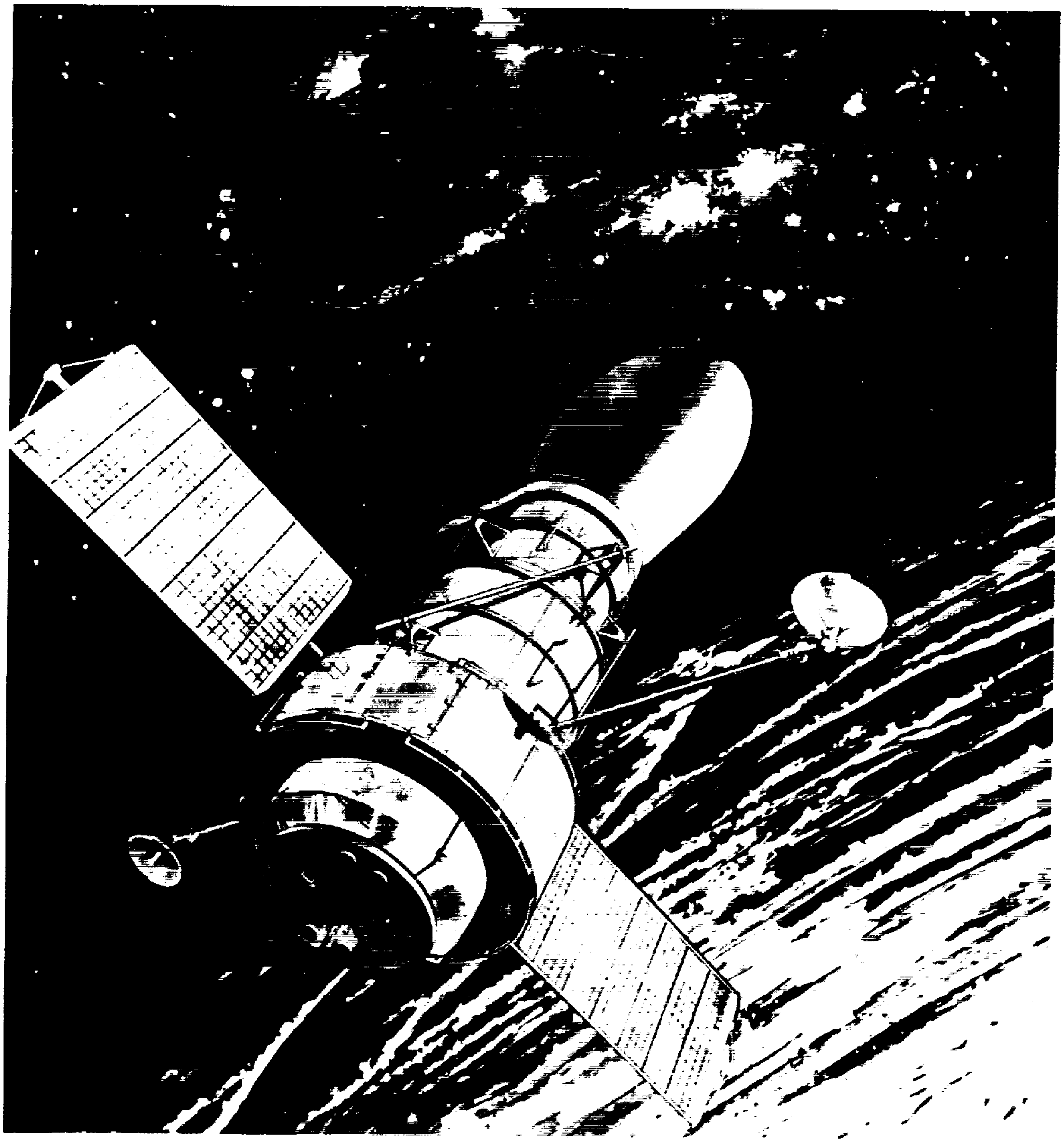


FIGURE 1.4. THE SPACE INFRARED TELESCOPE FACILITY

This cryogenically-cooled observatory will be the major observatory for infrared astronomy.

Satellite Servicing at the Space Station

One new technology that is crucial to the success of our research program is spacecraft servicing. The Solar Maximum Repair Mission, which restored the operation of a malfunctioning observatory, dramatically demonstrated the importance of servicing as an insurance policy against miscellaneous hardware failures. There are strong scientific and economic reasons for developing the servicing capability as an integral function of the Space Station. For astrophysics, long-lived observatories are necessary. If we intend to peer to the edge of the universe, we need enough time to find the interesting objects and investigate their physical condition. We cannot afford to lose our observatories because of hardware failures, empty fuel tanks, run-down batteries, or depleted cryogens; nor can we necessarily afford to send the Shuttle up on a service call every time something goes wrong. Instead, it makes sense for the Space Station to include an orbital service center equipped with tools, spare parts, and trained personnel prepared to repair failures, resupply consumables, and perform preventive maintenance to ensure long observatory lifetimes.

This servicing capability will be beneficial, in varying degrees, to each kind of astrophysics mission--attached payloads on the Space Station

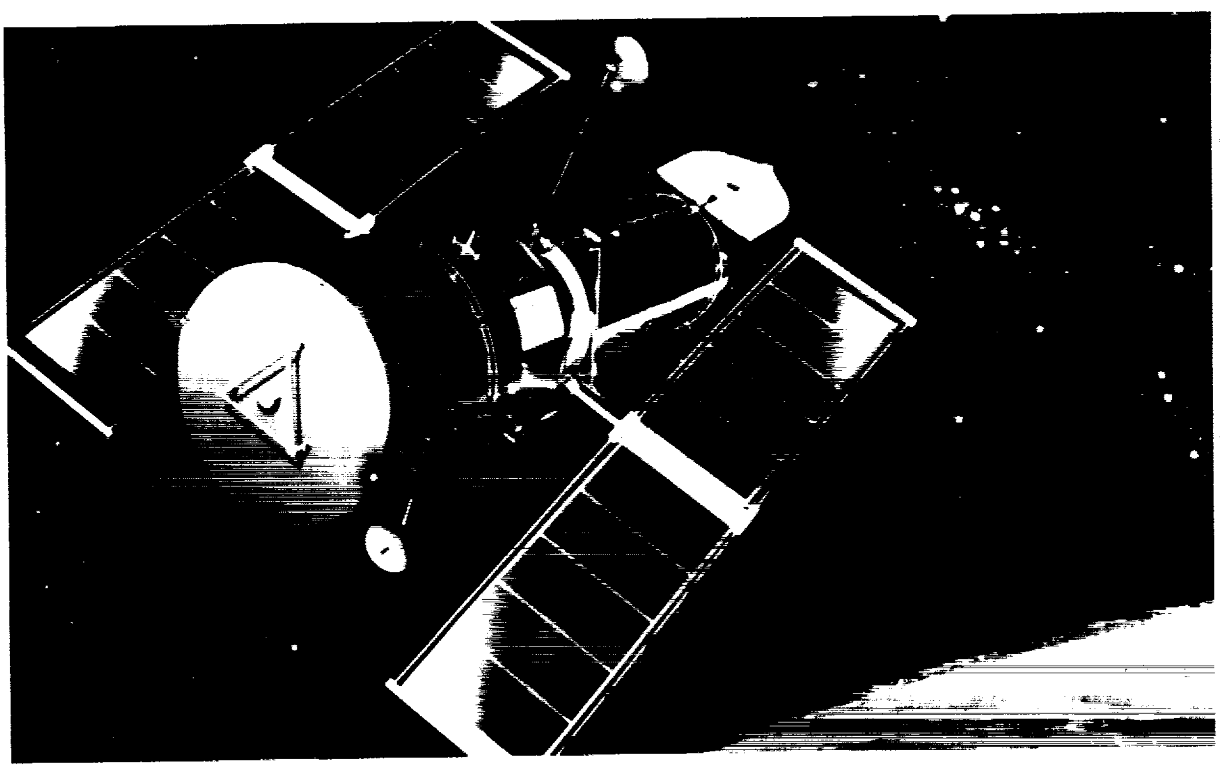


FIGURE 1.5. THE HUBBLE SPACE TELESCOPE

This major observatory for visible and ultraviolet light will begin operations in space in 1986.

itself, co-orbiting free-flyers, and our major observatories, such as the Hubble Space Telescope, the Advanced X-Ray Astrophysics Facility, the Gamma Ray Observatory, and the Space Infrared Telescope Facility. Just as observatories on the ground are routinely maintained, so our observatories in space will require regular inspection, cleaning, repairs, resupply, and upgrading. Since they will be in compatible orbits, it will be more convenient to maintain these observatories from the Space Station than from the Shuttle, and it will be less costly to service them in space than on the ground. For optimal use, our sophisticated observatories should be kept operational without extensive interruption; they are our capital assets in space.

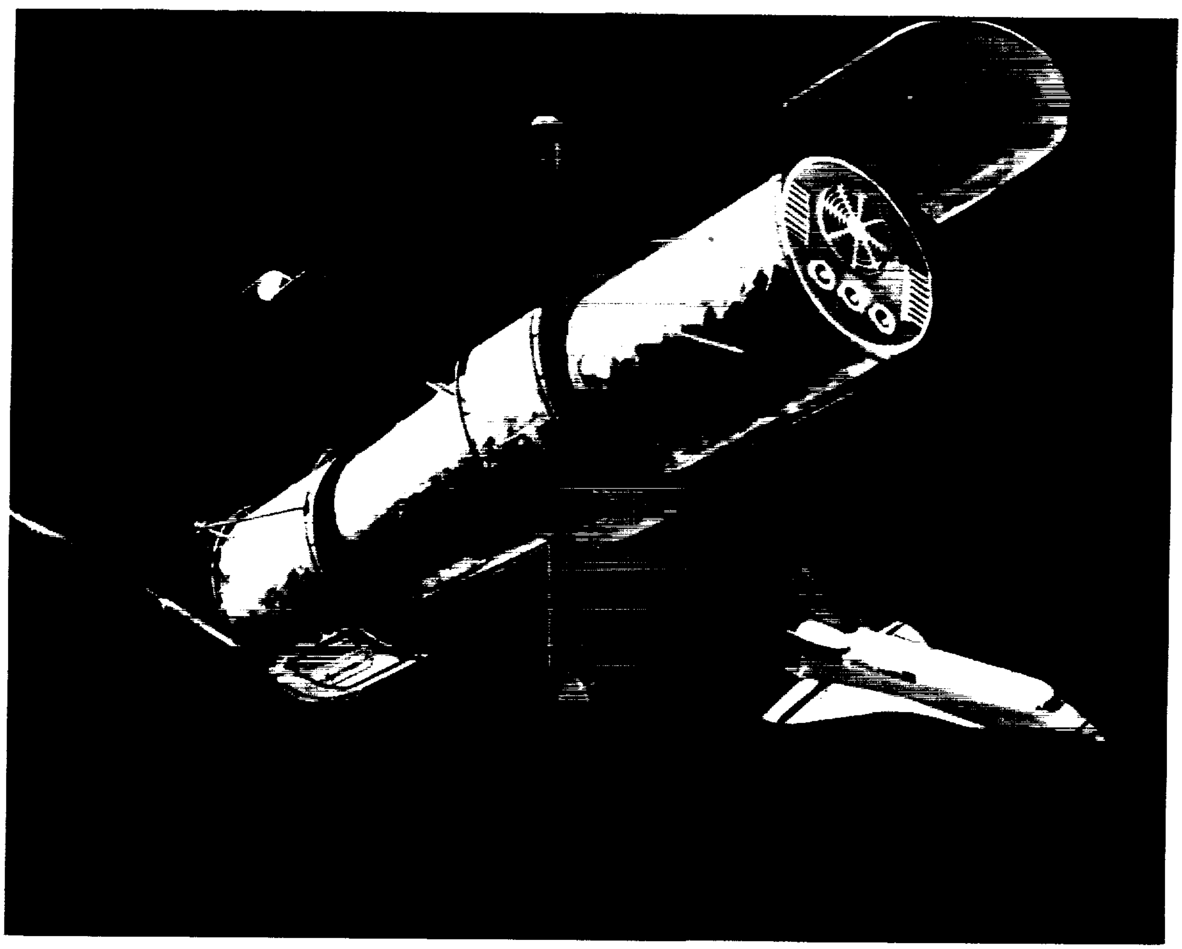


FIGURE 1.6. THE ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)

AXAF will be as significant an advance in x-ray astronomy as the Hubble Space Telescope is for visible and ultraviolet astronomy. Launch of AXAF is planned for the early 1990's.

In addition, the Space Station will play an important role in upgrading instrumentation in orbit to take advantage of new advances in technology. New detector technology is crucial to astrophysics research, for it enables us to increase the capabilities of new and existing telescopes. The instruments of the Space Station era will be of a sensitivity many orders of magnitude better than we thought possible just a few years ago. During the next few years, we expect many improvements in charge-coupled device array detectors, cryogenic devices, radio receivers, cosmic-ray and gamma-ray detectors, spectrometers, and coating materials.

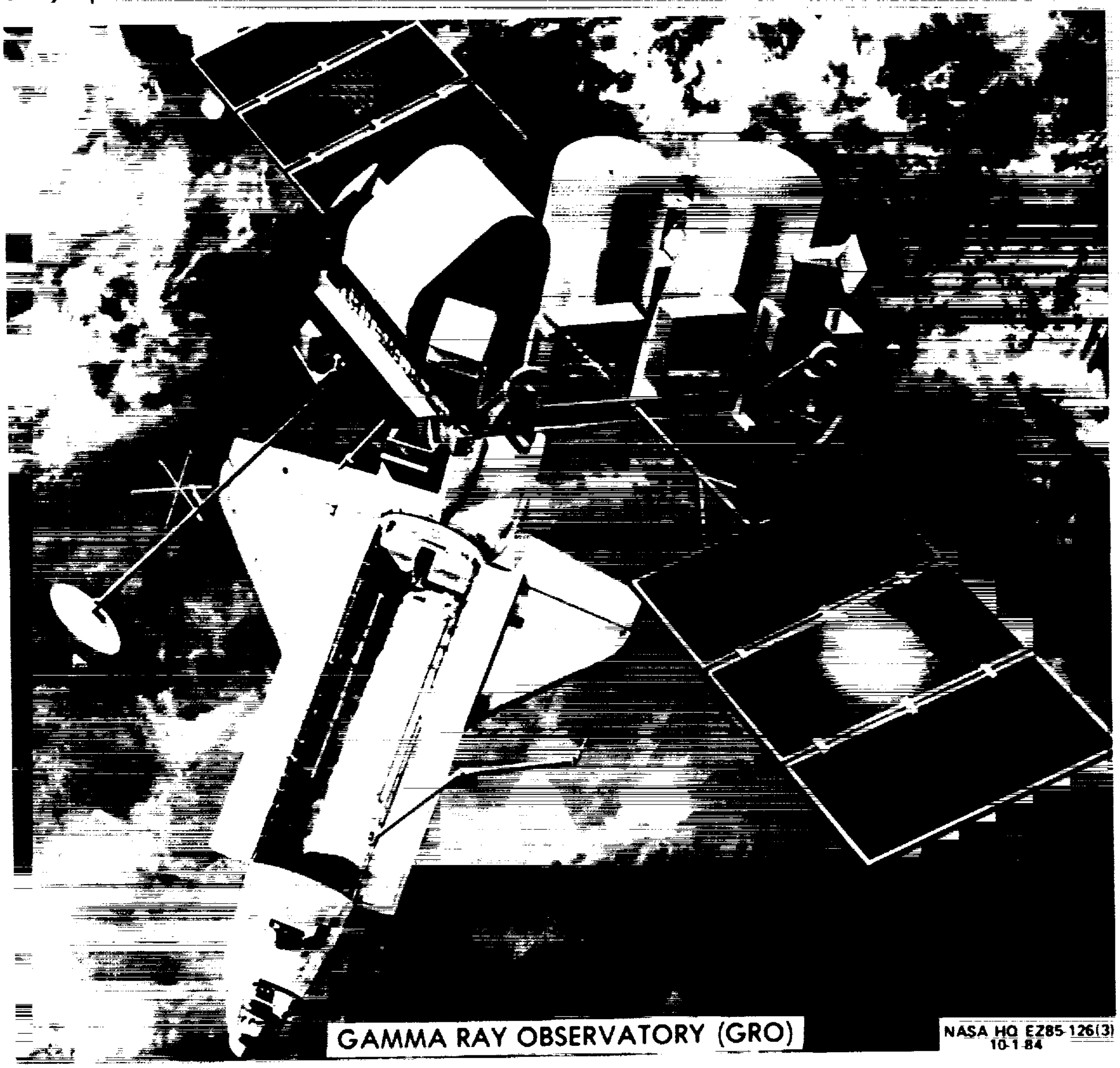


FIGURE 1.7. THE GAMMA-RAY OBSERVATORY

This is the first mission capable of observing the entire gamma-ray spectrum. It will be launched in 1988.

If instruments are designed for replacement and are accessible, members of the Space Station crew will be able to remove obsolete items and introduce state-of-the-art components. Upgrading scientific instruments in space, particularly by introducing new technology in the focal plane, will be a profoundly beneficial function of the Space Station for astrophysics.

As noted earlier, discovery keeps pace with advances in technology. Every missed opportunity to apply new technology to astrophysics research means a loss of potential knowledge. As a base for upgrading our instruments in orbit, the Space Station will save valuable time in maintaining state-of-the-art capabilities.

Volume 3 describes the servicing of astrophysics missions at the Space Station.

Assembling Astrophysics Missions at the Space Station

Another promising technology for astrophysics research enables us to build, in space, systems and devices significantly larger than can be carried into orbit by rockets or the Shuttle. The keys to progress in astrophysics are improved resolution and increased sensitivity. For some parts of the spectrum, this is achieved by using larger detectors spread over a greater area. For example, large instruments in space are necessary for spectroscopic and imaging observations in the far-infrared and submillimeter regions of the spectrum; to collect enough photons for analysis and to gain high angular resolution at long wavelengths, the proposed Large Deployable Reflector (LDR) is 20 meters in diameter.

The Space Station will play an important role as an assembly base for constructing and deploying large detector arrays. Parts will be delivered on multiple visits by the Shuttle and stored in readiness on the Space Station. There, an EVA construction crew, aided by the Remote Manipulator System, will be able to assemble and deploy large systems. Orbital construction activities will be a combination of automated deployment, human-operated robotics, and human assembly. Volume 4 first describes the scientific problems requiring large instruments, then some mission concepts, and finally some general technical requirements indicating the services that will be necessary for assembly late in the Space Station's lifetime.

Space Platforms for Astrophysics

The Space Station, with its servicing capabilities and its permanent presence, makes possible new concepts for spacecraft in both the observatory and Explorer classes. The long-lived astrophysical observatories that are developed to use the capabilities will also have the benefit of the technology developed for the permanence of the Station itself. The generation of spacecraft incorporating Space Station compatible technology and supporting these observatories has been called Astroplatforms to distinguish them from the generation that are based on Shuttle capabilities and technology. The Station generation starts with the Advanced X-ray Astrophysics Facility and the Space Infrared Telescope Facility.

Just as the major observatories are capital investments, so it will be possible for private business to invest in platform services in space. The Station makes it possible to change payloads every two or three years, and we are planning to use this new service as we implement our Explorer program.

Explorer missions for astrophysics are small instruments for specialized tasks. Two examples are the X-ray Timing Explorer (XTE), which is designed for long-term observations of a few bright X-ray sources, and the Far Ultraviolet Spectroscopy Explorer (FUSE), which will obtain spectra of very highly ionized interstellar and circumstellar gas.

Experience has shown that reducing the number of interfaces between unrelated activities is essential to keep system engineering from smothering in its own complexity. This is what leads us to continue with independent platforms that are the appropriate size for the facilities they are carrying. Besides observatories and Explorers, there will continue to be some payloads that can be handled by very small platforms that we call Space Station Spartans. These will carry small telescopes and provide spacecraft services for missions lasting from 1 to 3 months necessary for special investigations with new generations of instruments. These new instruments are the basis of all our future programs, and these small spacecraft will provide the opportunity for the new instruments to be fully tested in space before they are placed in our observatories.

In Volume 5, Observatory, Explorer, and Spartan missions for the Space Station generation are discussed. When these missions are under way, the Station will become the hub of space transportation where payloads can be exchanged and stored, freeing the Space Shuttle and various existing platforms to follow independent schedules.

REQUIRED SPACE STATION ATTRIBUTES FOR ASTROPHYSICS APPLICATIONS

As we seek ways to gain the best value for our investment in space, it is only prudent to consider what science we can do well from the Space Station and what accommodations the Space Station could provide to best meet our needs. It is clear that the Space Station figures prominently as an observatory base, service center, assembly site, and support node for a variety of missions. It is also clear that, for optimal utilization by astrophysicists, the Space Station must provide certain accommodations and services. Most of these accommodations, however, are necessary for many other uses of the Space Station and are not unique to the accommodation of astrophysics missions.

Desirable functional and architectural attributes are presented in each volume of this document. Some of the provisions deemed necessary on the Space Station are described below:

Observatory Needs

- Pointing and Stabilization
  - Fairly modest requirements for an unobstructed view of the Sun (solar physics) and space (cosmic ray physics); no specific attitude requirements
  - Isolation from vibration inputs above the capabilities of the Instrument Pointing System
- Low-Contamination Environment
  - Possible requirement for location away from Shuttle docking area
- Time
  - Uninterrupted duty cycle for solar instruments during sunlit portions of the orbit
- Command and Data
  - On-board processing and control capability for ASO
  - Versatile capability to handle extremely low (100 kbits, cosmic ray investigations) to extremely high (100 Mbits, Solar Optical Telescope) rates.

Servicing Needs

- Service Center
  - Dedicated work area designed and equipped for a variety of maintenance and repair activities
  - Improved grapple and holding devices for spacecraft capture
  - Berthing platform and temporary storage bay
  - Remote Manipulator System/Robotics
  - Manned Maneuvering Unit
  - Orbital Maneuvering Vehicle
  - Logistics base - inventory of spare parts, tools, consumables
  - Support equipment for extravehicular activity
  - Advanced Extravehicular Mobility Unit
  - Airlock and "shirtsleeve" environment.

Assembly Needs

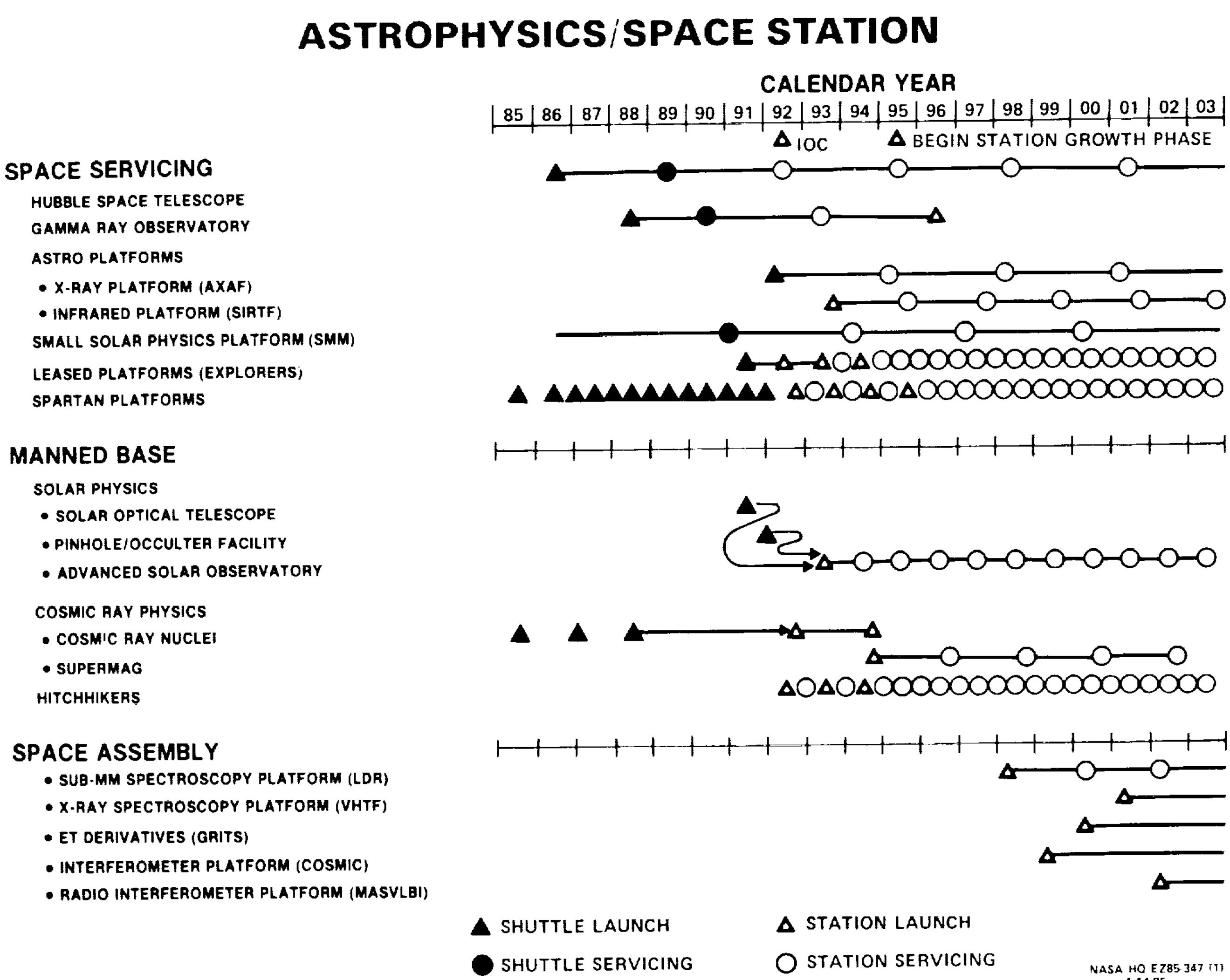
- Assembly Base
  - Construction site with provision to accommodate growing size and weight capacity
  - Standard tools
  - Advanced Remote Manipulator System, larger and more dextrous than the Shuttle RMS
  - Robotic assembly machines.

Support Needs

- Platform Support Node
  - Requirements and interfaces comparable to those for service center.

If the Space Station can meet these requirements, astrophysics research will be able to benefit from the Space Station's capabilities. Through servicing, we will be able to maintain our orbital observatories and extend the lifetime of our missions. Through on-orbit assembly, we will be able to construct very large instrument systems. We can also mount large instruments and evolutionary complements of instruments on the Space Station, and we can support a fleet of small free-flyers. Table 2 shows when we plan each major use of the Space Station.

The Space Station represents the next leap in our use of space as a worksite. There we will be able to do and build and see and discover things that are impossible on the ground. It is the purpose of this document to help focus our talents and imaginations on the challenge of defining astrophysics requirements for this very important new resource.



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